

## Chapter 6 Cranes and Hoists

### 6-1. General

*a. General.* Cranes and hoists are used in powerhouses for operational functions and for maintenance and repair. The general hoisting functions involved are similar for most powerhouses, but loadings, frequency of usage, powerhouse configuration, installed equipment, value of downtime, and availability of portable equipment can affect the optimum provisions for a particular project. Normally, initial planning should be on the basis of an existing project with similar requirements, but careful consideration of the variables should precede final selection of cranes and hoists.

*b. Terminology.* “Cranes” and “Hoists” are somewhat interchangeable terminology since the actual lifting mechanism of a crane is commonly referred to as a hoist. For purposes of coverage in this chapter, “Hoists” will be considered as separate items of equipment that include installations where the hoist machine is fixed and there is no controlled lateral movement of the hook(s) or lifting block(s). Other applications are covered under “Cranes.”

*c. Emergency closure.* For safety reasons, two different closure methods to shutoff the water supply to the turbine are required. One method is considered to be the wicket gates. The other method shall be a penstock shutoff valve (refer to Chapter 5), or an intake gate lowered by a hoist. Fixed hoists at each intake gate slot are used to lower the intake gates in an emergency situation. Intake gantry cranes are not normally used to lower intake gates in an emergency because of the much slower response time and potential crane-capacity problems.

### 6-2. Cranes

*a. Types.* Cranes for powerhouse requirements include several types: bridge, gantry, monorail, jib, mobile, and floor cranes. Coverage in this chapter is as follows:

(1) Powerhouse bridge crane. The principal overhead traveling crane serving the turbines, generators, and auxiliaries in typical indoor powerhouses.

(2) Powerhouse gantry. A gantry-type crane serving the same functions as the powerhouse bridge crane for outdoor powerhouses or in unusual cases involving a special structural design of indoor powerhouses.

(3) Intake gantry. A gantry-type crane serving intake gates, trashracks, bulkheads, fish screens, and miscellaneous items on the intake decks of powerhouses.

(4) Draft tube gantry. A gantry-type crane serving stop logs, bulkheads, and miscellaneous items on the tailrace deck of powerhouses.

(5) Mobile crane. A self-propelled, rubber-tired crane for general use, principally on intake or tailrace decks and miscellaneous nonpowerhouse project functions.

(6) Maintenance shop bridge crane. A maintenance shop bridge crane, usually a trolley-mounted electric hoist suspended from a single girder bridge, serving equipment in the maintenance shop.

(7) Floor crane. A light, portable crane with wheels for mobility on powerhouse and maintenance shop floor areas, normally manually being propelled.

(8) Monorail crane. A trolley-mounted, motorized or manual, hoist running on an I beam track for special applications.

(9) Jib crane. A wall or pillar-mounted, rotating bracket with an electric or manual hoist for specialized lifts with limited horizontal movement requirements.

*b. Preliminary considerations.* For each powerhouse, the following preliminary considerations should precede design and specification work on the individual cranes:

(1) Items handled. A preliminary listing of all major items to be handled by powerhouse cranes during construction, operation, maintenance, and repair should be prepared. The listing should include estimated weights, pickup and set down points, and the crane to be used.

(2) Area layouts. For each crane, layout drawings should be prepared showing points at which the crane must pick up or set down material, including loading or unloading of trucks and railroad cars, intermediate or transfer points, maintenance and repair areas, and equipment installation points. These layouts should include points for required lifts and points or areas at which crane lifts may be desirable but not required. Areas which may be used as storage or warehouse areas should be indicated also. Lifting or handling of heavy items (e.g. a small transformer), which may require moving for which crane service is not planned, should be indicated along with the proposed means of handling.

(3) Coordination. The preparation of the listing of items to be handled and area layout drawings should include information exchanged with construction and operation divisions as well as other engineering responsibilities. All reasonable adjustments in equipment location to provide effective and economical crane service should be negotiated also.

(4) Miscellaneous preliminary considerations. Corrosion mitigation is discussed in paragraph 19-2.

*c. Engineering and design.* Most engineering and detail design criteria for powerhouse cranes are covered in engineering manuals and guide specifications as referenced herein under the particular crane type. Final detail design and construction of cranes are responsibilities of the supplier as provided under the procurement contracts. The responsibility of the powerhouse design office is to obtain and coordinate all preliminary information noted in paragraph 6-2*b*; to determine requirements for each crane based on the preliminary information; to prepare crane clearance drawings based on sufficient design studies; to assure a practical and economical crane; to prepare specifications; and to review shop drawings, design computations, and operating instruction manuals. Documentation of assumptions and reasons for selecting particular lifting procedures and equipment arrangements should be a part of the design records. The preliminary studies and coordination are important in obtaining the optimum crane for the required service, and shortcuts should not be made.

*d. Bidder qualifications.* Bidder qualifications are not normally an engineering responsibility, but in the case of powerhouse cranes, it is particularly important for the powerhouse mechanical designers to exert their influence in obtaining qualified contractors. Providing cranes ready for service on schedule is very important to avoid impact to overall powerhouse construction schedules. Contractors inexperienced in design and construction of cranes have caused costly delays and impacts to other construction work. Many times a two-step bidding process is prudent in order to obtain a quality product on schedule.

*e. Powerhouse bridge cranes.*

(1) General. General criteria and design procedures, along with data on existing cranes, are available in EM 1110-2-4203. Detail design criteria for indoor bridge cranes are covered in Guide Specification CW-14330. For outdoor powerhouses, the powerhouse crane will normally be a gantry type for which design criteria noted in Guide Specification CW-14340 should be used as indicated in paragraph 9 of EM 1110-2-4203. Coverage

herein is limited to additional general factors which enter into crane requirements and crane selection. The discussion is applicable particularly to powerhouses with conventional vertical units; however, most factors noted are also applicable to cranes servicing slant or bulb units. Some slant units may require two cranes, one upstream and one downstream, because of horizontal distance between generator and turbine. Special intermediate lift and handling facilities are usually involved with either slant- or bulb-type units. These special facilities should be determined and furnished by the generator and turbine contractors subject to the normal design office shop-drawing reviews.

(2) Number of cranes. The choice of providing one or two cranes is an important consideration in powerhouses with several units or heavy capacity requirements. Factors entering into this determination are:

(a) Procurement cost. This cost considers one crane versus two.

(b) Powerhouse structural costs. A single crane may increase structural costs because of greater physical size, though generally only moderate additional cost is involved.

(c) Construction and erection advantages of two-crane availability. Two cranes will usually be more beneficial in long multiunit powerhouses and may have significant advantages where the construction schedule requires continued erection work after several units are in operation.

(d) Additional crane clearance. The necessity to provide two-crane lifting beam configuration will increase the roof height.

(e) Hook coverage limitations. Unusually large capacity single cranes result in greater floor areas not accessible to a lifting hook.

(f) Additional maintenance cost. Maintaining two cranes versus one does increase this cost.

(g) Value of unit downtime. Two cranes may expedite maintenance or repairs.

(h) Comment relative to two cranes for bulb or slant units (see paragraph 6-2*e*(1)). Seldom will two cranes be justified in powerhouses with less than five units. For five or more units, the design memoranda should include

the considerations pertinent to the selection of one or two cranes.

(3) AC versus DC drive systems. Current technology of AC variable frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(4) Crane capacity. EM 1110-2-4203 includes guidance for determining crane capacity. In applying the criteria the engineer should be aware that numerous factors beyond engineering control tend to disrupt orderly scheduling, and it will frequently be necessary to prepare contract drawings and specifications for cranes before accurate final loads are determined. It is also sometimes necessary to firm up powerhouse structure design affected by crane capacity and clearances prior to final confirmation of lifting loads. In such cases, capacity should be based conservatively on estimated loads (to avoid later increases). Loadings due to planned or potential future units should also receive consideration in determining crane capacity and be included in the design computations. It has been the Corps of Engineers practice to specify crane ratings that allow up to 10 percent overload for infrequent special heavy lifts such as the generator rotor when a preferred crane rating falls within this range. For cranes designed in accordance with Corps of Engineers guide specifications, this overload is well within the allowable stresses permitted by the Crane Manufacturers Association of America (CMAA) standards and is in accordance with ANSI standards and OSHA'S interpretation of their regulations.

(5) Appearance. Powerhouse bridge crane appearance should be consistent with the interior finish of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(6) Access. In the early stages of powerhouse layout, convenient and safe access to bridge cranes should be considered. In larger powerhouses, the vertical distance from erection areas to the crane cab level may be 15 m (50 ft) or more. This makes it desirable to provide access from a level served by an elevator when practicable. Access via convenient stairs is preferred when elevator service is impracticable, but the most common access,

particularly in the smaller powerhouses, is via ladders. A ladder located to permit direct access to the cab elevation is preferred. Via corbel, bridge, and ladder descent into cab is the least desirable means of access but is acceptable when required by powerhouse arrangement. The crane "parking" location should be reasonably close to the principal crane use area. Safety is the first consideration in crane access, and architectural emphasis should not be at the expense of either safety or convenience.

(7) Drawing. Typical powerhouse bridge crane clearance and coverage diagrams appear in Appendix B, Figure B-1.

*f. Powerhouse gantry cranes.*

(1) General. General considerations noted in paragraph 6-2e(1) are applicable. Powerhouse cranes of the gantry type are usually limited to outdoor powerhouses. In the case of an indoor powerhouse such as Libby Dam in Montana with construction making it impractical to support bridge crane rails, a gantry or semigantry may be required. There has been very limited application for such cranes in Corps of Engineers projects, but data on the Libby crane are available from the Hydroelectric Design Center, North Pacific Division, Portland, Oregon, for reference purposes. The design generally should follow applicable criteria for outdoor powerhouse gantries.

(2) Number of cranes. More than one gantry crane will seldom be justified since cost and bulkiness tend to offset the advantages. Portable equipment can usually be utilized for major work at outdoor powerhouses further diminishing the value of a second crane.

(3) DC versus AC drive systems. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(4) Crane capacity. Comments in paragraph 6-2e(4) are applicable. In cases where additional hoists are provided serving the functions of draft tube gantry cranes or intake gantry cranes, capacity of those hoists should be as described in paragraphs 6-2h(5) and 6-2g(5).

(5) Appearance. Comments in paragraph 6-2e(5) are applicable.

g. *Intake gantry cranes.*

(1) General. The powerhouse intake gantry crane may be utilized as a dual-purpose powerhouse intake-spillway crane but is more commonly restricted to powerhouse intake service. Intake deck-hoisting requirements vary widely from project to project, and good judgment is required to select the optimum provisions for each crane. Present publications of crane design data on existing projects do not include intake gantry cranes. However, data on existing cranes, to meet most new requirements, are available, and sources can be obtained on request from the Office of Chief Engineers, Washington, DC. Coverage herein includes general factors pertinent to the selection and type of equipment. Detail design criteria are included in Guide Specification CW-14340.

(2) Intake gantry lifting functions.

(a) Intake gates and bulkheads. The heaviest lifts normally involve handling of the intake gates and bulkheads. Trolley-mounted hoists permit handling of the gates and bulkheads with the same hoist. Routine raising and lowering, maintenance support, and transfer to storage slots or other repair locations are normal requirements. In some instances, the crane is used during gate delivery and erection; however, construction scheduling usually requires contractor cranes being available for gate erection. Intake gantry cranes are not used to lower intake gates in an emergency because of the potential load capacity problems resulting from gate hydraulic downpull in addition to the slow response. The total time for a crane crew to come on site, pick up an intake gate, travel to the affected generating unit, lower the intake gate, and repeat the sequence to install the other two intake gates is much too long to avoid major damage to the unit and protect the integrity of the powerhouse. Even if the intake gantry crane was built with three hoists to carry three intake gates to provide faster closure, the response time is still too long.

(b) Fish guidance equipment. Raising and lowering fish guidance equipment, such as submerged traveling screens or submerged bar screens, and vertical barrier screens, is a major task for intake gantry cranes at some powerhouses. Additional provisions are needed to handle fish guidance equipment, such as tugger hoists, an auxiliary hoist, faster main hoist speeds, and additional lifting devices. Careful planning is needed to assure all needed provisions are included in the crane design.

(c) Trashrack service. Raising and lowering of trashrack sections and raking of trashracks are common intake

gantry crane functions where distances from gate and bulkhead slots to trashracks are moderate. For wider decks, use of a standard commercially available rake and hoist unit or a separate trashraking crane is more practical.

(d) Handling of individual gate hoists. Where individual gate hoists are provided, placement and removal is normally an intake gantry crane function, and the clearances for hydraulic cylinders, load transfer supports, and procedures for raising and lowering cylinders between vertical and horizontal positions require careful planning.

(e) Transformer handling. Where main power transformers located on intake decks are within the crane load rating otherwise required, loading and unloading of the transformers is a common crane function. Increasing crane capacity, hook coverage, or number of hoists for transformer handling alone is seldom justified as temporary facilities are practical for the infrequent movements.

(f) Loading and unloading of rail cars and trucks. Intake decks are usually accessible to trucks and, in some cases, rail cars. Crane clearances and hook coverage should provide convenient handling.

(g) Miscellaneous lifts. As applicable, miscellaneous lifts should also be considered in crane design. Lighter lifts may be made using mobile cranes, but availability, accurate control, and safety usually favor the use of an intake gantry crane.

(3) Number of cranes. More than one intake gantry crane will seldom be justified.

(4) AC versus DC drive systems. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(5) Crane capacity. Crane capacity should be determined in accordance with Guide Specification CW-14340.

(6) Appearance. Intake gantry crane appearance should be consistent with the intake deck area of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(7) Dual-purpose cranes. Use of the intake gantry for both intake deck and spillway deck functions should be considered where usage for routine operational purposes is not required on either deck. Agreement should be obtained from the operations division involved on the acceptability of a dual-purpose crane.

*h. Draft tube gantry crane.*

(1) General. The principal function of a draft tube gantry crane is to handle the draft tube bulkheads. Alternate provisions are sometimes practical and should receive consideration. This includes using a monorail hoist where deck configuration and slot location are unsuitable for a gantry or a mobile crane, or where there will be only one to three units. Then the project will have a mobile crane available full time for other purposes. Commercial monorail hoists are generally restricted to about 4.5-tonne (5-ton) lifts. Mobile cranes are less desirable for operating convenience and safety reasons, so procurement of a mobile crane specifically for handling draft tube bulkheads is not recommended. Detail design criteria for draft tube gantry cranes are included in Guide Specification CE-1603.

(2) Lifting functions.

(a) Draft tube bulkheads. This function will determine the crane rating.

(b) Deck slot and hatch covers.

(c) Fish facility equipment. At projects where fish facilities are incorporated in the draft tube structure, the draft tube crane may be required to handle gates, bulkheads, stop logs, machinery, weirs, diffusers, etc.

(3) Number of cranes. One draft tube gantry will provide all required service.

(4) DC versus AC drives. Current technology of AC variable-frequency drives enables them to have performance similar to a DC drive, and the cost is approximately the same. One advantage of the AC drive is reduced maintenance since induction motors do not have brushes as DC motors do. The guide specifications list several alternatives to be determined for each specific application.

(5) Crane capacity. Guide Specification CE-1603 should determine this capacity.

(6) Appearance. Draft tube crane appearance should be consistent with the tailrace area of the powerhouse. It is usually advisable to rely on the powerhouse architect for determination of an acceptable appearance, but compromises are necessary where preferred appearance impairs maintenance, full utility, or safety.

(7) Trolley. For draft tube bulkhead service alone, a fixed hoist in accordance with Guide Specification CE-1603 is adequate. If other service such as fish facility handling is required, a trolley-mounted hoist in accordance with Guide Specification CW-14340 may be justified.

*i. Mobile cranes.* Mobile cranes will seldom be furnished specifically for the powerhouse since they are normally an item of general project equipment. They are usually specified to match an existing, commercially available item. The powerhouse design should consider which powerhouse lifts will be handled with a mobile crane, the loads, and required hook travels and boom lengths. Special slings, lifting beams, and lifting eyes to achieve required safety factors usually have to be provided for each type of lift.

*j. Maintenance shop bridge crane.*

(1) General. All required lifting and transporting operations in the maintenance shop can be accomplished with an economical floor crane plus a minimum of temporary rigging. The provision of the more costly bridge crane requires considerable justification. Since a bridge crane can expedite handling, the potential for a heavy volume of essential work in the shop at one time would be the principal justification. Project work external to the powerhouse, as well as work from other projects, should be considered. For powerhouse work alone, 10 or more main units along with a fully equipped shop will usually justify a bridge crane in the maintenance shop. Design criteria for maintenance shop bridge cranes are available in Guide Specification CW-14601.

(2) Crane characteristics. It is preferable that the crane be kept as simple as practical, avoiding the more sophisticated control options and writing the specifications around generally available catalog equipment. Single-speed hoist control in the range of 0.06-0.09 m/s (12-18 fpm) is satisfactory. Powered trolley travel is available as a catalog item and is justified. Powered bridge travel is also justified, particularly in the case of a long narrow shop. Hoist and powered travel push-button

controls should be located in a pendant-type box. Capacity should be 1.8-4.5-tonne (2-5-tons).

(3) Precautions.

(a) When a bridge crane appears justified, early planning is required to assure a powerhouse structural layout permitting adequate shop ceiling and lighting clearance for the bridge.

(b) Structural support for the crane rails is an early planning consideration.

(c) Specifications should require a bridge and hoist capable of withstanding pullout torque forces applied to the hook.

*k. Floor cranes.* Maintenance shops not equipped with a bridge crane should be provided with a portable floor crane. This will include essentially all shops in 1-4-unit plants and many shops in 5-10-unit plants. The crane should be a standard catalog item, preferably hydraulically-operated, manually-powered, and equipped with antifriction bearing wheels and casters. A 1.8-2.7-tonne (2-3-ton) capacity should be specified.

*l. Monorail cranes.* The most common powerhouse application for monorail cranes is handling of draft tube bulkheads at small powerhouses where the slot location is close to the downstream wall. Rated capacity and maximum lifting stresses should meet Guide Specification CE-1603 requirements. Standard catalog units are preferred, but proof-testing of the hoist and rail to pullout should be required. Other powerhouse handling applications with lifting and travel requirements in restricted areas may warrant monorail installations. Before a monorail decision is made, each requirement should be carefully evaluated for practical alternate provisions, such as embedded lifting eyes and portable hoists or crane hook access hatches permitting lifts to be made with the bridge crane or a deck gantry. Monorail hoists have had some application in maintenance shops but lack the versatility of a bridge or floor crane. Design criteria for monorail cranes are available in Guide Specification CW-14340.

*m. Jib cranes.* Jib cranes have limited application in powerhouses since most areas with adequate head room to accommodate a jib can be serviced with the bridge crane or a deck gantry. They are most suited to hoisting applications requiring limited horizontal movement, as on or off a truck, or a limited transfer movement to or from a location just beyond bridge or gantry crane hook coverage, and locations where an embedded eye and portable

hoist are impractical. Mounting of a jib crane on a gantry crane leg to handle hatch covers, gratings, or heavy maintenance equipment is sometimes an advantage. A good selection of standard catalog jib cranes is available. Manual winches or chain hoists are normally adequate for jib use. Electric hoists are justified if they will be used frequently. The uncertainty of maximum loading with a manual hoist makes it important that jib structural members and anchor bolts be designed with high safety factors. Design criteria for jib cranes are available in Guide Specification CW-14340.

### **6-3. Crane Lifting Accessories**

*a. General.* Crane lifts may require one or more intermediate devices connecting the crane hooks or blocks to the load. Certain lifts require a device for supporting the load in storage or intermediate positions. These devices include lifting beams, adapters, spreader beams, support beams, and "dogs." Standard rigging-type slings should normally be selected and procured by construction or operations offices. Spreader beams, support beams, and "dogs" will usually be either bought with the crane or equipment. Powerhouse bridge-gantry equipment differs appreciably from intake gantry and draft tube crane equipment, and coverage herein is divided accordingly.

*b. Powerhouse bridge-gantry lifting accessories.*

(1) General. Lifts made by the powerhouse bridge or gantry cranes are accessible for visual observation and also to personnel for attachment and release. This permits design based on known loads and manual means of connection and release.

(2) Lifting beams.

(a) General. Cranes with more than one main hook require lifting beams to connect the hooks to generator rotor and turbine runner assemblies. A single beam is required with a single, two-hook crane and three beams with two, two-hook cranes. The beams should provide convenient manual connections of the load to the crane hooks, essentially moment free, vertical lifting forces on the load, and stable operation under all loaded or unloaded conditions. These lifting beams are normally designed and furnished under the crane contract.

(b) Design. Data on existing beams are included in EM 1110-2-4203, and detail design requirements are in Guide Specification CW-14330. Cooperation between the crane contractor and generator-turbine contractors to assure fit and utility of the lifting beams will be required

under the supply contracts. However, it is a responsibility of the contracting office to monitor the exchange of information for timing and accuracy. The design office is usually required to do preliminary design and beam layout to assure a practical powerhouse structural layout and crane clearance diagram.

(3) Adapters and attaching devices. Adapters for fitting the lifting beam to the generator rotor and turbine runner assembly are made a responsibility of the generator-turbine contractor under the supply contracts.

(4) Slings. Slings for major lifts of the powerhouse bridge-gantry cranes are not required. Lifts requiring slings utilize standard rigging.

(5) Drawings. Figure B-1 illustrates conventional lifting beam configuration as part of a typical crane clearance diagram.

*c. Intake gantry and draft tube gantry crane lifting accessories.*

(1) General. Intake gantry and draft tube gantry cranes are regularly used for handling gates, bulkheads, stoplogs, and fish guidance equipment below the water surface where the point of attachment to the load is non-visible and nonaccessible to operating personnel. Obstructing debris or silt can hinder operations, and “cocking” or “binding” of the load or lifting beam in the slots can occur. Slings remaining attached to the submerged load or lifting beams with dependable remote control of latching and unlatching are required. Most lifts can be made with either an attached sling or a lifting beam, and the selection should be made only after careful consideration of the following factors:

(a) Dependability. In all cases, dependability favors an attached sling since the potential for latching and unlatching problems, as well as the uncertainty of a secure latch having been effected, is eliminated.

(b) Sling size. Sling size may become large enough to cause handling and storage problems.

(c) Hook travel limitation. Limited crane hook travel combined with deep load settings may require several dogging operations with slings and a consequent impractical time requirement.

(d) Multiple unit loads. Where more than one gate, bulkhead, or stoplog section are required in a single slot, slings are usually impractical. Design of lifting

equipment for underwater loads should normally be based on pullout or maximum controlled torque lifting forces. Exceptions should be clearly noted and justified in the mechanical design memorandum. The expense and hazards of diver operations to remedy faulty operation plus monetary loss from delay in returning generator units to service warrant maximum design emphasis on reliability.

(2) Lifting beams.

(a) General. Lifting beams may be provided for intake gates and bulkheads, draft tube bulkheads, trash-racks, fish guidance equipment, and for miscellaneous small gates and bulkheads in water conduits, fish channels, and sluices. Weight-operated latching mechanisms with manual tagline unlatching is preferred except where physical size of latches or pins make manual operation nonfeasible. Tagline operation should be assumed a one-man effort, and maximum required rope pull should not exceed 223 N (50 lb<sub>p</sub>). The design should have clearances and dimensions that provide source engagement of alignment pins with sockets, hooks with latches, and latching pins with sockets with all accumulated construction and installation tolerances considered. Beam length to guide height proportions should minimize wedging tendencies in guides, or end clearances should preclude wedging. Weight of lifting beams is normally a minor factor in total lifting loads; therefore heavy and rugged designs are desirable to stand up under severe operating conditions and to ensure positive lowering and latching through debris. Multipurpose beams requiring a variety of special adapters, special guide shoes, length or offset adjustments, and interchange of hooks are not recommended. An assembly drawing for each beam should be included in the mechanical design memorandum showing slots, load pins, beam hooks, aligning pins when applicable, guide shoes or rollers, operating mechanism and critical dimensions, tolerances, and clearances indicating correct operation under all conditions. Figures B-2 and B-3 include drawings of a typical intake gate-bulkhead lifting beam and a manual hook-release type lifting beam, respectively.

(b) Intake gate, bulkhead, and fish guidance equipment beams. A single lifting beam is normally provided for intake bulkheads, gates, and fish guidance equipment. Early coordination of gate, bulkhead, fish guidance equipment, and slot design to assure a practical single lifting beam without adapters is necessary. Procurement is usually included in the intake gantry crane supply contract, and final design is made a contractor's responsibility. Initial design criteria are included in Guide Specification CW-14340.

(c) Miscellaneous beams. Basic structural and mechanical unit stresses should be in accordance with the applicable requirements of Guide Specification CE-1603 with normal loadings considered as lifting loads plus friction and pullout loadings based on the applicable crane hoist. Pullout loadings for mobile cranes should be considered as boomup tipping load. Hooks should be mechanically linked together to assure simultaneous movements.

(3) Slings. Special purpose slings for intake gantry and draft tube gantry crane use should be made of corrosion resistant rope and galvanized fittings. Ultimate strength of sling assemblies should provide a safety factor (FS) as shown in Table 6-1 based on the maximum load. The slings should normally also have a FS of 2 based on the hoist pullout torque, maximum controlled torque, or crane-tipping load. Exceptions should be clearly noted and justified in the mechanical design memorandum. A lesser FS may be used provided that by detailed analysis, it can be shown that under imbalanced load conditions a FS of 5 is provided for the sling leg or lifting beam components having increased loads. Sling clevis pins and other pins requiring disassembly under normal use should have ample clearance to minimize binding under average field-handling conditions. A 1.6-3.2-mm (1/16-1/8-in.) clearance is preferred for average field-handling convenience. Design of intermediate links, storage links, support beams, and sling storage provisions should consider convenience and safe handling along with required strength.

#### 6-4. Hoists

*a. General.* Fixed hoist applications in powerhouses include operation of intake gates requiring emergency closure capability, operation of gates and weirs requiring automatic or remote control, and miscellaneous lifts non-accessible to a crane. Fixed hoists may be of several

types, the most common being hydraulic and drum-wire rope. Portable equipment is preferable to fixed hoists from a maintenance standpoint and should be considered for all applications with infrequent, noncritical usage.

##### *b. Intake gate hoists.*

###### (1) General.

(a) Fixed gate hoists. These hoists are applicable for vertical lift, wheeled, or roller-mounted gates. The main purpose of fixed hoists is to provide emergency closure. The normal use of fixed hoists will be for maintenance and repair operations. Potential conditions which could require emergency closure include loss of wicket gate control, head cover failure, an inadvertently opened or failed access hatch, or precautionary closures during abnormal operation. The frequency of such emergencies is recognized as remote. However, the potential for major damage does exist, and the emergency closure provisions of fixed hoists are justified. The design should provide maximum dependability and rapid closure under remote control plus backup manual closure under power failure. In addition, necessary provisions for normal gate operations should be included. The type of hoist selected will depend upon the size of gates involved and the configuration of the intake structure. The three types of fixed hoists generally considered are direct acting hydraulic hoists, hoists consisting of hydraulic cylinders connected by wire rope through deflector sheaves to the gates, and drum-wire rope hoists.

(b) Performance criteria. Closure of all gates on a single unit should be accomplished simultaneously and within 10 min from initiation of the closure sequence. The lowering speed of the gate at the point-of-contact with the sill should not exceed 0.05 m/s (10 fpm). Gate-raising speeds are not critical. Depending on size, it is

**Table 6-1**  
**Safety Factors**

Application	FS for Load Visually Observed	FS for Load not Visually Observed
For permanent crane or hoist not involving slings	5 x ML*	5 x HC*
For permanent crane or hoist utilizing bridle slings	5 x ML	8 x HC
For permanent crane or hoist lifting beam (without slings)	5 x ML	5 x HC
For mobile crane use	5 x ML	8 x ML

\* ML = Maximum load to be picked up; HC = Hoist capacity rated.

\*\* FS to be increased in cases where a significant load imbalance between two or more slings is possible (based on the maximum possible load imbalance which the hoist can exert on a sling or lifting beam member, such member shall have a FS of 5).



usually satisfactory to take 10-20 min to open a gate. When the penstock or power tunnel is filled by cracking the intake gate, it is essential to fill the tunnel slowly in order to avoid sudden changes in pressure. This is done by allowing the intake gate to creep to about 3 percent open before opening at normal speed. Intakes utilizing gates with upstream seals and a limited area behind the gates have developed dangerous gate-catapulting forces during filling. Emergency closure should be possible under complete failure of the normal power supply.

(2) Hydraulic hoists.

(a) General. Hydraulic hoists normally consist of a single acting cylinder, pumps, reservoir, controls, and piping. The preferred arrangement is to place the cylinder above the gate and support it in the slot. The rod is connected to the gate, and the gate and rod hang from the piston. Adding or releasing oil from the cylinder controls the gate position. Two cylinders per gate are common for large gates. Where intake and deck elevations do not permit hanging the gate below the cylinder, it may be necessary to recess the cylinders within the gate structure. All intake gate hoists in a powerhouse are normally connected to a common pump-piping system, and system pressure is maintained above the minimum pressure required to prevent gate drift. A typical hydraulic circuit and cylinder drawing are shown in Figures B-4 and B-5, respectively. Guide Specification CW-11290 provides guidance for hydraulic power systems for civil works structures. Complete drawings and specifications of existing satisfactory designs can be obtained from the Hydroelectric Design Center (HDC), North Pacific Division, Portland, Oregon.

(b) Hoist capacity. Maximum hoist capacity will be determined by the load because of emergency shutdown of the unit, or opening the gate to equalize unit to pool head.

- Hydraulic downpull load. The emergency shutdown load is composed mainly of gate deadweight, hydraulic downpull load resulting from high-velocity flow under the gate, head on the gate upper seal, and deadweight of the rod. Hydraulic downpull will vary greatly, depending on configuration of the gate bottom, static head, and location of the skin plate and seals. In most cases, the load caused by the hydraulic downpull will be the major load that the hoist will see in emergency shutdown. Extreme care must be taken when determining these loads. More information on hydraulic downpull can be obtained from the HDC.

- Seal breakaway load. The equalizing load is composed mainly of gate deadweight, seal friction, roller chain or wheel tractive load, and rod weight. Seal breakaway friction tends to be unpredictable as it depends on type of seal, surface condition, seal material, elapsed time with seal under head, and seal preload. However, it can be of greater magnitude than the maximum downpull forces. Maximum downpull load should not occur simultaneously with seal breakaway load. Normal gate movements are made under balanced head conditions and usually involve essentially only gate and rod buoyant weights, seal friction, and roller chain tractive load. The design hoist capacity should be conservative, reflecting the indeterminate nature of major loads. Hoist loadings on a variety of existing gates, based on hydraulic system pressure gage readings, can be obtained from the HDC.

(c) System design operating pressure. A 20,670-kPa (3,000-psi) design system pressure is recommended. Hydraulic components for this pressure are very common. Required hoist capacity can usually be obtained with practical cylinder sizes using 20,670-kPa (3,000-psi) pressure as well. Operating pressures for normal balanced head gate movements or for holding gates in the open position will usually be within 8,270-13,780-kPa (1,200-2,000 psi) when cylinders are designed for maximum downpull and breakaway loads at 20,670-kPa (3,000-psi) operating pressure.

(d) Cylinder. Internal diameter and nominal external dimensions of the cylinder should be determined by the design office, but final cylinder design should be made a contractor's responsibility. The cylinder should be of one section with heads bolted onto the cylinder flanges. There are different types of flanges that could be used and should be open to the contractor.

(e) Rod. The outside finish of cylinder rods must be of corrosion resistant material. Base material should be of high strength to minimize rod displacement and, in most cases, must have good welding and machining properties. Specifications and contract drawings should include material options appropriate to the required rod, rod dimensions, coupling provisions, finishes, physical properties, and special fabrication and testing techniques. The following four satisfactory options for the base material are normally available:

- Chromemolybdenum steel rods with hard chrome-plated surface. This option provides an excellent

rod at reasonable cost when rod dimensions are within capacity of commercial plating facilities.

- Chromemolybdenum steel rods with formed and welded on monel cladding. Although satisfactory service is obtainable by this method, fabrication problems are to be expected unless the fabricator is experienced in such work. Specifications should emphasize to prospective bidders the requirement for fabrication experience.
- Solid, age-hardening, stainless rods. Rod materials of this type offer good strength, weldability, and corrosion resistance. They are becoming increasingly available and are an acceptable alternate when competitively priced.
- Ceramic-coated rods. These rods have a sprayed-on ceramic coating that is very durable and impact and corrosion resistant. Care should be taken to assure qualified fabricators apply this type of coating.

(f) Latch. A manually engaged latch should be provided to lock the piston and rod in the retracted position for raising the gate to the dogging position with the crane. The engagement is normally a threaded connection in the top of the piston rod with the latch pin located in an oil-sealed hole in the cylinder head. The latch pin should be of corrosion resistant material. A removable T-wrench should be provided to permit convenient operation of the latch pin.

(g) Pumps. Pumps are positive displacement piston or vane type with standard catalog ratings to provide required displacement and pressure. Delivery should be sufficient to open a single gate in approximately 20 min or less. It is usually desirable to provide the required displacement with two identical pumps to provide backup in the form of reduced speed raising in event of pump failure. It is usually also desirable to provide makeup oil to maintain pressurization of the system with a separate small displacement pump to avoid frequent starting or continuous unloading of one of the raising pumps. Delivery should be 150-200 percent of anticipated leakage. The small displacement pump may have a higher pressure rating than the raising pumps to aid in breaking loose a gate for equalizing. Pumps should be mounted to provide a positive suction head and be equipped with auxiliaries recommended by the manufacturer. Relief or unloading valves should be provided to limit maximum stress in hoist components to 75 percent of yield point. The

75 percent yield-point pressure should be the maximum relieving pressure to which the valves can be adjusted.

(h) Valves.

- Lowering valves. Lowering valves should be essentially drop tight at gate support pressure, should operate within their catalog flow rating at required lowering flows, and should be suitable for remote control of opening. Cylinder-operated, shear-seal type valves and pilot-operated check valves are two that are in satisfactory service. Solenoid valves in the pilot circuit are normally used for remote control to open the valve. Valve closing should be manual only to minimize possibility of accidental raising of a gate on an unwatered unit. Two valves in parallel should be provided to allow emergency closure in event of a single-valve malfunction. The lowering valves should be suitable for emergency manual operation, or separate manual lowering valves should be provided.
- Flow control valves. An adjustable pressure-compensated flow control valve should be provided in the high-pressure line from each cylinder to regulate gate lowering speed and to match lowering speeds where more than one gate per unit is required.
- Manual valves. Manual valves should be of the quick-acting, low-operating force type suitable for panel mounting. A valve should be provided in the high-pressure line to each cylinder to permit individual manual gate control and to isolate the cylinder from the hydraulic system.

(i) Pump controls.

- Pressurization-breakaway pump control. The pressurization pump should be on automatic start-stop pressure control to maintain system pressure above minimum no-drift pressure. A manual momentary-contact override switch should be provided at each panel to permit applying temporary breakaway pressure. Pump relief-unloading valve settings should normally be about 5 percent above normal maximum system operating pressure.
- Raising pump controls. Raising pumps should be on manual start with adjustable time-switch

shutdown. Remote start should be provided at each unit hydraulic control panel.

(j) Control panels. Gate movement controls and valves for one main unit should be mounted on one common control panel at each unit, generally in a gallery near the gate slots. A steel panel designed for standard panel-mounted hydraulic valves is preferred. A similar panel should be provided near the pumps for pump controls.

(k) Piping. High-pressure piping of Schedule 80 seamless with socket welding fittings is satisfactory. Low-pressure piping is normally Schedule 40 with socket welded fittings. Due to both internal and external corrosion problems, the piping should be stainless steel such as American Society of Testing and Materials (ASTM) A312, Grade TP304. If it is necessary to utilize two oil reservoirs on a single system, the equalizing header between them should be substantially oversized to preclude overflow from unbalanced return flows. Low-pressure piping should be sized to provide a positive head throughout the system unless there are minor, short duration, negative pressures under emergency closure operation.

(l) Reservoir. A reservoir sized to contain the displacement of all piston rods on the system plus the volume of one cylinder, 15 percent reserve oil, and 15 percent air volume should be provided. Reservoirs should have an interior painted finish conforming to MIL-C-4556. Reservoirs should be located to assure a positive system head and should be heated as required to preclude condensation.

(m) Accumulators. Accumulator capacity on the system should be sufficient to ensure a pressurizing pump cycling time of not less than 10 min.

(n) Support beam. The cylinder support beam of structural steel should be accurately fabricated, stress relieved after welding, and machined on bearing surfaces to assure uniform bearing loading. Connection of the cylinder to the beam with separate nuts on extended cylinder head bolts is recommended. The support beam should fit over locating dowels on the support pads and should be bolted down to preclude movement if subjected to upward forces transmitted through the cylinder rod.

(o) Gate position indicator. When gate position indicators are not otherwise provided, they should normally be included with the hydraulic hoist design. They are essential with hydraulic hoists to monitor gate position and to obtain prompt indication of gate drift. Stainless

tapes connected to the gate tops with tension maintained by counterweighing or spring take-up reels have given satisfactory service.

(p) Design. Design of the hydraulic hoist system is usually a responsibility of the government. Service and size requirements are usually not compatible with commercially available catalog equipment, and suppliers' special designs are contractually difficult to control. The design should be adaptable to a variety of pumps and control valves, seals, piston rings, cylinder construction, etc., to avoid unnecessary bidding restrictions.

### (3) Wire rope hoists.

(a) General. Wire rope hoists are applicable to intake configurations requiring gates with deep submergence or gates with shallow settings, either of which make hydraulic hoists undesirable. Unusually deep gates require several rod extensions resulting in slow installation and removal of cylinder-operated gates. Shallow gates may require portions of a hydraulic hoist to be above deck level interfering with movement of vehicles over the deck. Individual stationary hoists are usually provided for operating each service gate. The gates are normally held by the motor brake in the operating position just above the waterway, and control switches are provided at the unit governor cabinets and in the control room to permit rapid closure in an emergency. Arrangement of the hoists varies greatly depending on the intake configuration. Hoists may be located below or on the intake deck adjacent to or over the gate slots. When located on the deck over the gate slots, provisions should be made for uncoupling the hoist blocks when the gates are in the upper dogged position, and for removal of the hoists from over the gate slots to permit transfer of the gates to the gate repair pit by use of the intake gantry crane.

(b) Description. Each hoist consists of a cable drum or drums and a system of sheaves and blocks which are electric motor driven through an arrangement of shafts, speed reducers, and spur or helical gears. The motor is usually 460-V, 3-phase, 60-cycle, squirrel-cage, induction type with suitable enclosure. Two speeds are sometimes provided to permit lowering at approximately twice the raising rate. The hoist brake is of the shoe type, spring set, DC magnet-operated type, with a watertight enclosure and a capacity of not less than 150 percent of the full-load torque of the motor. The wire rope is of stainless steel with an independent core. During normal operation, the lower block is immersed, with part of the associated reeving immersed and part exposed. When the hoist is

located on the intake deck over the slots, the hoist machinery should be mounted on a platform of sufficient height, so that the gate can be hoisted to a dogging position where it can be readily uncoupled at intake deck level. With this arrangement, the hoist machinery frame and support columns form an integral structure designed to support the hoisting machinery and gate including provisions to permit its removal from over the gate slot by use of the intake gantry crane. Base plates with locating pins should be provided in the intake deck structure to permit quick and accurate resetting of equipment. Machined bearing pads to support machinery components, necessary openings to provide clearance for ropes and moving parts, and grating to permit inspection and maintenance should be provided. A minimum area of open grating should be provided for airflow when the supply is through the service gate slots in which the required area should be based on a maximum air velocity of 45 m/s (150 fps). Sockets embedded in the intake deck concrete permit installation of safety handrailing around the gate slots when grating and/or hoists have been removed. The motor controller for each hoist should be housed in a watertight control cabinet supported from the hoist frame. A traveling nut-type or intermittent geared type high-accuracy limit switch and a dial-type gate position indicator, as well as a slack cable limit switch, balanced pressure switch, and an extreme upper travel limit switch, are provided. Accuracy of limit switch trip and reset should be considered when gate cracking or other similar accurate positioning is needed, especially for gates with long travel. Removable power and control plugs should be furnished to permit disconnecting of all incoming leads to the hoist prior to its removal.

(c) Design. Each gate hoist should be designed for a rated capacity equal to the sum of the gate weight, roller chain tractive load, seal friction, and maximum hydraulic vertical forces with normal stresses. Mechanical parts of the hoists should be designed for the rated capacity with a minimum FS of 5 based on the ultimate strength of each component. In addition, mechanical components should be designed to withstand the forces produced by hoist motor-stalled torque with resultant stresses not in excess of 75 percent of yield point of the materials involved. Reducers should be sized in accordance with American Gear Manufacturers Association (AGMA) Standard for Class I Service using conservative values for starting and running efficiencies. Wire rope hoists should be in accordance with the requirements of Section 5 of Guide Specification CW-14340. Hoist capacity and speeds should follow paragraphs 6-4b(1)(b) and 6-4b(2)(b). Wire rope should be of corrosion resistant material.

(d) Location. Wire rope hoists should be located on the deck when practicable. Locations in recesses below the deck may be required where deck access would be impaired by a deck location. Controls along with reliable gate position indicators should preferably be located in a gallery close to deck elevation.

(e) Power failure operation. When it is necessary to make provisions to lower the gates without power, brake release and means of speed control should be provided, such as a hydraulic pump driven by the hoist motor with an oil reservoir and flow control valve. If a hydraulic pump is used, a dual-purpose hydraulic pump-motor replacing the electric hoist motor should be considered.

*c. Miscellaneous wire rope hoists.*

(1) General. Fixed wire rope hoists may be required for lifting applications inaccessible to cranes or for control gate operation where frequent adjustments or automatic controls are necessary. Portable commercial equipment is preferred whenever practicable. Powerhouses with fish passage facilities frequently require fixed hoists for weir adjustment and control gate operation. Fixed hoists may occasionally be justified for ice and trash sluice control gates. Fish facility equipment criteria are normally supplied by fishery agencies; however, powerhouse design responsibility includes safety, dependability, and satisfactory service life.

(2) Design. Wire rope hoists should comply with the applicable requirements of Section 5 of Guide Specification CW-14340. Corrosion resistant wire rope should be used for all applications where any part of the line will operate submerged. Underwater bearings should be water lubricated except where presence of abrasive silt requires sealing. The cost of miscellaneous wire rope hoists is often moderate and may not appear to justify extensive engineering. However, several factors can affect satisfactory operation, maintenance, and service life. The design procedure should not shortcut the necessary investigations which include the following:

(a) Climatic conditions. These conditions include the effects of icing, moisture, and heat.

(b) Water quality. The presence of abrasive silt or unusually corrosive materials in the water should be considered.

(c) Gate guide alignment, material, and clearances. These factors, while not primarily a mechanical design

responsibility, can materially affect hoist operation, so coordination with the responsible design group is necessary. The possibility of gates temporarily “hanging-up” is often overlooked.

(d) Water hydraulic conditions. The possibility of unusual turbulence, surging, or wave action causing added hoist loading, uplift, or vibration should be investigated.